The French experience of post-mining management

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THE FRENCH EXPERIENCE OF POST MINING MANAGEMENT

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ABSTRACT: *The proposed paper presents the French mining historical context that lead to the present situation. Recent evolutions of the French mining legal scope specifically dedicated to post mining management are explained and the systematic prevention policy adopted in France is described, including the major tools used to assure the post mining risks prevention and management process. Finally, some information concerning a first assessment of work progress and experience feedback of the last decade is synthesised.*

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KEYWORDS: Post-Mining, Risk Management, Prevention, MRPP .

RESUME : L'article présente sommairement le contexte historique minier qui a conduit à la situation actuelle. Les récentes évolutions du Code Minier concernant la gestion de l'après-mine sont ensuite expliquées et la politique de prévention systématique des risques adoptée en France est décrite, en s'appuyant notamment sur les principaux outils de prévention et de gestion des risques récemment développés. Pour finir, un état des lieux de l'avancement des travaux et du retour d'expérience acquis durant les dix dernières années est proposé.

MOTS-CLEFS : Après-Mine, gestion des risques, Prévention, PPRM..

1. Introduction

During centuries, the French mining activity contributed, for a large part, to the national industrial development. However during the last few decades, due to the combined effect of the resources exhaustion and international competition, the very large majority of French mining sites gradually closed down.

The closure and abandonment of mining sites do not result in the complete and definitive eradication of risks for people, activities and goods located in the area of influence of abandoned mines. Some potential occurrence of hazards and disorders on surface may persist at long term in the surroundings of former mining works. ln addition to potential ground instability phenomena (subsidence, sinkholes, etc.), some mining sites may be affected by dangerous gas emissions, flooding events or environmental degradations. These effects can occur as soon as the mining extraction stops but also in certain circumstances, long time after closure.

The paper presents a brief overview of the French mining activity. It then identifies and describes the technical and legal context that leads to the elaboration of the French post-mining prevention policy. This policy is then discussed, including a brief overview of the French mining legal scope recent evolutions as well as a description of the major prevention programs and procedures that are developed in France. Finally, a short description of the post-mining risk management organisation is proposed, in order to explain the co-ordination between public services or establishments involved in the post-mining risk management process.

2. French Mining Historical Context

Like many other European countries, France has a long mining tradition. The extraction of raw materials contributed, in a decisive way, to the French industrial power development.

On the French territory, the first signs of underground extraction of mineral resources (old flint mines, salt springs) may be roughly dated of the Neolithic era (5th to 3rd millennium. BC). Before the Roman occupation, Celts and then Gallics regularly exploited gold and tin (1st millennium BC). It is however during the Gallo-Roman period that the mining activity really developed with the beginning of silver, lead, copper and iron exploitation.

The mining activity then took the form of a multitude of local small-scale mining sites, distributed throughout the whole country (Ist and IInd centuries). After the fall of the Roman Empire, mining exploration and extraction declined during nearly one millennium. Under the influence of Central Europe development and in order to satisfy the increasing economic needs resulting from demographic expansion and political stabilisation, prospecting and mining activities became again national priorities (XIth – XIIth centuries). During this period, coal started to be exploited in the Hérault and Provence basins (SE of France) as well as in the Saar area (NE of France). It is however the industrial revolution (XVIIth – XVIIIth centuries) which has driven the development of the French mining activity.

Technological improvement contributed to transform an activity, which up to that period was mainly small-scale, into a real industry. In addition to the composition of large mining basins (coal, iron, salt), which contributed largely to the prosperity of the national economy, the beginning of the 19th century was also characterised by an important diversification of exploited minerals (oil, manganese, fluorite, zinc). In spite of an overall unfavourable context (priority accorded to the colonial development, economic crisis of 1929), the mining activity continued to develop during first half of the 20th century, mainly due to the two World Wars.

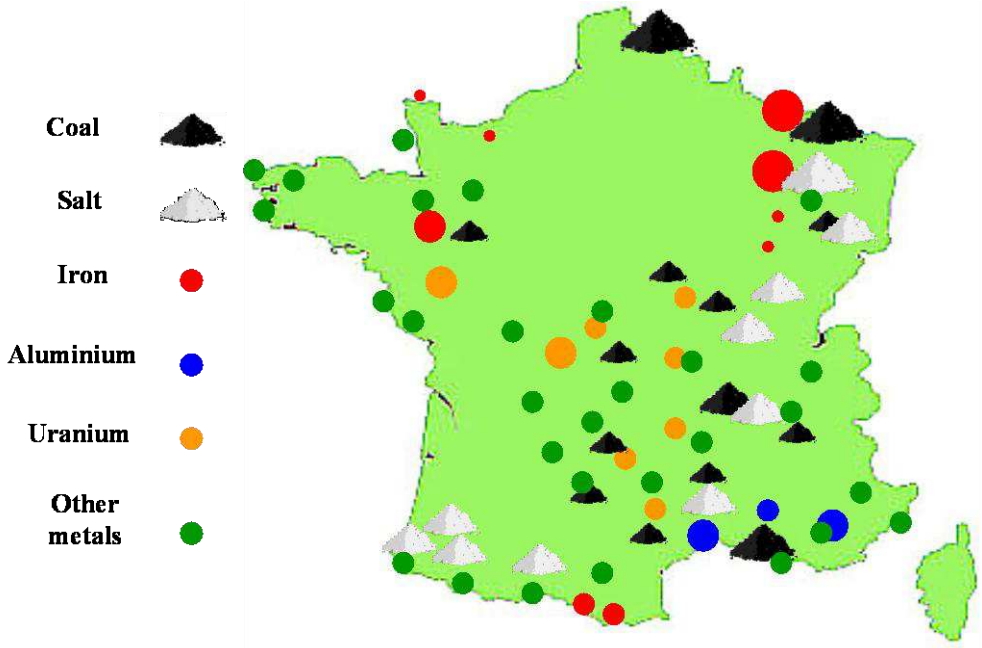

Figure 1. Major mining fields having been exploited in France

After the Second World War, the mining activity was developed once again in order to rebuild the country and also to limit the nation's energy dependence towards other European countries. The production of coal and lignite increased thus quickly to reach 60 million tons in

1958. During this period, efforts were made in oil exploration and the first uranium large fields began to be exploited. The development of the geochemical techniques and geophysics and the important improvements carried out in the field of prospecting enabled the discovery of several important sites mined out successfully by French mining companies.

The significant decline of raw material prices and/or the exhaustion of some major fields gradually generated the decline of the French mining activity. Initiated at the beginning of the sixties for coal and iron and at the beginning of the eighties for the mining of the other substances, this decline accelerated since the early nineties. The closing of the last iron mine occurred in 1995 and the last uranium mine closed down in 2001. The mining of potash stopped in 2003 and the last extraction of coal panel closed down in 2004. From now on, the only active mining industry in Metropolitan France results mainly from the extraction of salt, by underground or by solution mining.

France has now to handle "post-mining" management. This new situation and the induced problems led the French State to take decisions and develop tools and competencies in order to manage properly the post-mining period. One should not forget that this heritage, often embarrassing for the new generations confronted to serious harmful effects, is the direct consequence of a past strategic activity, which strongly contributed to develop the French industrial power.

The priority of France is now to optimise the re-development of the areas directly affected by the progressive closure of mining activities, which used to be sources of employment and prosperity for local inhabitants. This step requires a very careful analysis in terms of land use management and regional planning. It is important to identify and locate as accurately as possible the potential risks and/or harmful effects that may develop and affect people, goods and activities after mining extraction.

As soon as this expertise has been performed, it becomes possible to report the risk to the public and take the technical measures adapted to each context, allowing the development of new activities in the safest and most adequate zones.

3. Context of the elaboration of the French post-mining prevention policy

The Abstract and Résumé as well as the Keywords and Mots-clefs are in 12 pt Times New Roman italic font, justified, 6 pt space after (“Abstract” Style). Leave a blank line between Keywords and Résumé sections, as well as before and after the entire unit. Use small caps for the words “*ABSTRACT*” and “*KEYWORDS*,”, “*RÉSUMÉ*”, “*MOTS-CLEFS* ”, as in the example above.

3.1. Recent post-mining disorders in the Lorraine iron ore basin

In 1995, the last iron mine closed down in Lorraine (NE of France), after almost one century of mining extraction. Consequently, the dewatering system stopped with, as a logical consequence, the progressive rise of the water level within the underground mining works.

In October 4, 1996, few months after beginning of the flooding process, a major subsidence event occurred in the city of Auboué, with a vertical amplitude of about two meters. The phenomenon generated severe damages to houses roadways (figure 2). About 70 buildings had to be demolished and 150 families victims of the damage had to be re-located. In the following months, other instabilities developed in the nearby cities of Moutiers (90 families moved in may 1997), Moyeuvre, Roncourt, etc.

Figure 2. Damages generated by the Auboué subsidence event.

Other types of disorders also developed at the same period: flooding of basements, oxygen deficient air in cellars connected to the mining galleries due to mine gas accumulation, etc.

These disorders provoked a real emotion among the population, who was already hardly affected by the economic difficulties, related the mine closure and the decline of the steel industry (Vila & al., 2001). The local population was organised in “defence associations” in order to express requests in terms of: victims compensation, post-mining risks prevention and re-development and land-use management of the post-mining area (more than 100 cities are located in the Lorraine iron ore basin). In parallel, the subsidence events initiated an acknowledgement, at top level of the State, of the serious need for a "post-mining” management policy. Innovative and adapted answers to those sensitive problems were then instigated and some improvement of the French mining legal scope were rapidly proposed, including a new mining works closure procedure (Didier & al., 1999). Moreover, GEODERIS, a public expertise body dedicated to the technical support to the administration in charge of post-mining risk management was also founded.

Systematic risk elimination over the entire region rapidly appeared to be strictly impossible. It would have required the use of hundreds of million cubic metres of backfill, which was technically and financially unreasonable, or the transfer of population to an extent, which was also impossible at a regional level. Since the number of instabilities fortunately remains reasonable (about 1/year), risk management has been organised in order to guarantee, as a first priority, public safety. For this, it was necessary to distinguish the mining sectors above which the potential surface instabilities could develop suddenly, generating disorders potentially dangerous for people, and the sectors above which disorders were limited to progressive subsidence that may damage properties without being dangerous to people (Didier & al., 2003).

A methodology separating these two kinds of subsidence events was thus developed (El Shayeb & al., 2001). Applying the identified criteria to risk zones beneath buildings enabled to recognize the sectors that may be affected by continuous subsidence (about 1,000 ha within the Lorraine iron ore basin) and those where the risk of sudden collapse was not excluded (about 100 ha).

The high-risk zones (possible discontinuous subsidence) are systematically backfilled or evacuated depending on the cost of mitigation scenario). For the other areas, the risk level was evaluated on the basis of the surface factors of vulnerability, the significance of effects and the susceptibility of underground mining works to collapse (Piguet & al., 1999). Monitoring,

mainly based on micro-seismic measurement of failure initiation in rocks, was then implemented for the most sensitive areas (Couffin & al., 2003).

To take benefit of the risk analysis process, a technical assistance was given to local authorities in term of land-use management, concerning the acceptability (or not) to develop urbanism on surface. This was the first step of the "Mining Risk Prevention Plans" concept.

3.2. Post-mining management in other countries

In every country concerned by post-mining issues, mining operators are considered to be the first, when not the only, responsible for the compensation of damages resulting from mining activity as well as cost generated by abandoned mining site rehabilitation (Petit, 2004). However, due to the progressive "demise" of mining operators, the National or Regional Authorities are progressively required to be involved in financing and managing the post-mining period (Drebenstedt, 2006). Some countries (Germany, England, Australia, United States, etc.) have created national establishments specifically dedicated to the operational treatment of post-mining damages.

In many countries (Belgium, England, Australia, etc.), an important effort is being made to perform an inventory of abandoned mine sites that may affect public safety (identification, location, data base constitution…) in order to optimise the prevention policy (Strickland & al., 2006). In all these countries, the Authorities wonder about the best way of giving notice of the identified or suspected risk. The objective is that people avoid building in areas that may be affected, at term, by post-mining damages.

In Belgium, for example, *non-aedificandi* areas are prescribed around mine shafts and above shallow mining works (galleries). People who want to settle in previous mining areas need to refer to the local Administration regarding mining context before buying the plot. In England, the Coal Authority delivers each year numerous "Mining Reports". Solicitors constitute the most frequent users of this service, mainly due to the necessity for them to provide those data to the purchasers in case of property bargain.

3.3. Natural hazard management in France

Long time before the Lorraine triggering events, natural hazards (flooding, forest fires, rockfalls, etc.) were managed in France in terms of risk prevention and land-use management. French law n° 82-600 of 13 July 1982, dealing with the compensation of victims of natural disasters, defines Risk Exposure Plans (REP). However, the difficulty in drawing up these plans (especially in terms of the vulnerability analysis) leads to long delays in their implementation.

French law n° 95-101 of 2 February 1995, relative to the reinforcement of environmental protection (now included in articles L.562-1 to L.562-7 of the Environment code) gave rise to the Natural Risk Prevention Plan (NRPP). Since risk definition is a part of the State's authority, the order, production and approval of NRPP is under the Prefect's responsibility (La documentation française, 1997).

After few years of feedback in the field of natural risk management, NRPP is the only tool of French natural risk prevention policy. The government objective to reach 5000 NRPP approved in 2005 has been successfully completed. This reflects a strong desire of the State to complete these prevention tools.

4. Post-Mining Management Policy in France

4.1. French Mining Legal Scope and its Recent Evolution

In France, the difference between mines and so-called “quarries” is made according to the type of extracted material. Under French Law, the exploitation of materials defined as "eligible for concession" is ruled by the regulations on mines, and the exploitation of materials defined as "non-eligible for concession" is ruled by the regulations on quarries. The materials "eligible for concession" include mineral substances, which were considered in 1810 as strategic and of prime importance for national sovereignty. These substances are mainly oil, gas, coal, salt, potash and metals. On the contrary, quarries are mainly used to extract building material (limestone, chalk, gypsum, slate, etc.).

In France, landowners have no right over the underground minerals or substances eligible for concession. Indeed, mines are subject to the "concession" rule. "Concession" refers to a contract, signed between the French State and a legal person or corporate body, authorising the exploitation of the substance subject to the contract against a fee. The word "concession" is also used to define the area granted to this person or body to perform his or its activity. Therefore, the concession is the administrative entity of reference in Mining Law.

The French mining legal scope stipulates that when the mining activity ceases (concession revocation or waiver), the exploited area returns to the “concessible” domain. If the former operator has disappeared or is failing, the State is responsible for any eventual annoyance resulting from mining. Taking into account available feedback of the Lorraine iron ore basin crisis, French State decided to deal with the post-mining problems in applying a systematic prevention policy in order to identify potential harmful effects before they occur. The final objective is to develop knowledge and expertise enabling prevention of future accidents and social crisis. This policy represents a kind of “bet”, assuming that the large amount of money invested in the prevention step will be cost-effective on a long-term basis by reducing drastically victims and damages compensating costs.

To apply this ambitious policy, the French mining legal scope was considerably reinforced during the last decade. Several major acts have thus been voted by French Parliament related to the post-mining. In parallel, some prevention tools and programs were initiated and implemented under the responsibility and co-ordination of GEODERIS with the objectives of identifying the potential risky areas and proposing most adapted mitigation options for the most sensitive ones. These major elements are discussed in the following paragraphs.

4.2. The “Mining Works Opening Procedure”

The decree n°2006-649 of 2 June 2006, related to mining activities and underground storage explicitly specifies in its article 6 all the documents requested to constitute a proper “Mining Works Opening procedure”. Among them, the mining operator need a document indicating, on a purely estimated basis, the mine closure scenario as well as a rough estimate of its cost. Thus it is now necessary to anticipate the closure of mining work and to prepare the management of the post-mining period even prior to the beginning of the exploitation. The quality and the relevance of the suggested closure scenario contribute to the acceptability of the opening procedure.

This anticipation approach perfectly fits the risk prevention. It indeed makes it possible to avoid the too many cases known in the past for which exploitations stopped without neither any planning nor any optimised preparation during mining activity. All the international specialists of mine closure agree today on the fact that the closure of a mine must be planned

(Mackenzie & al., 2006) even prior to the opening (rehabilitation financing plan, mobilisation of competencies...).

4.3. The "Mining Works Closure Procedure"

Over the last few years, the growing awareness of safety and environmental issues, as well as the knowledge obtained through the latest mine closures, led the French Government to reinforce the legal procedures pertaining to the closure of mining works. The French Government notably decided to integrate the notion of mine works rehabilitation in the mining laws and regulations in order to secure the concerned sites and limit their impact on the environment. In accordance with the French Mining Code, the Concession-Holder must, from now on, notify the steps to be planned in order to reduce future potential harmful effects (surface movements, gas emission, pollution, etc.) that may jeopardise public safety and health or the main characteristics of the environmental surroundings.

The Concession-Holder must transmit a "mining works closure application" to the Préfet (French regional administrative authority) at least six months before the definitive closure of all or a part of the mining works. The French Mining Code defines precisely the content of this application. The Concession-Holder, after a general presentation of the sites concerned by the closure application from the geological, hydrogeological and operational standpoints, must establish a list (in terms of quality and quantity) of the consequences that the underground works have already induced on the environment. It must then endeavour to assess the long-term consequences of the definitive closure of the works. Finally, he must define the possible counter-measures, which he considers as most appropriate and which could guarantee a hazard level in compliance with the surface occupation.

The application is then examined by the various administrative services concerned as well as local councils. Therefore, the document must be sufficiently detailed and precise in order to allow experts to express on the quality of the performed studies and relevance of the suggested counter-measures. However it must also be understandable by non-specialists (mayors, members of associations, etc.).

Once he has acknowledged the application, the Préfet can either validate the technical proposals or prescribe further measures which were not planned by the Concession-Holder but are felt necessary. If the Concession-Holder fails to complete the prescribed works, the Prefect designates a third party to perform measures required to secure the site at the Concession-Holder's expenses. The Préfet notifies the final closure works by publishing a decree confirming that the measures implemented by the Concession-Holder are in compliance with the application or the additional securing measures.

Following the request of the French Ministry in charge of Industry and Mines, INERIS has developed a methodological guideline describing the recommended procedure to prepare and/or to evaluate this so-called "mining works closure application". This document, established in 2001 is of great help for mining operators as well as Administrative services in order to optimise the technical content as well as the duration of the whole procedure (INERIS, 1999).

4.4. The "Mining Risk Prevention Plans"

Parallel to the step of "Mining Works Closure Procedure" which has to be fulfilled by the Concession-Holder's, it is the State responsibility to evaluate and report the residual risk and to integrate it in the management of the regional planning. To standardise and optimise various approaches dealing with risk prevention, the French State decided to extend the pre-

existing Natural Risk Prevention Plans (NPPR since 1995) to Mining Risk Prevention Plans (MRPP since 1999) and then Technological Risk Prevention Plans (TRPP since 2003).

The major risks taken into account in Mining Risk Prevention Plans are, in particular, surface instability, flooding, dangerous gas emission, dangerous ground or water pollution, ionizing radiation. PPRM presents two major objectives (Didier & al., 2005):

- Identification of the areas which are the most sensitive at the long term, to risks or harmful effects related to mining.
- Establishment of prevention, protection and safety measures adapted to the various post-mining constraints for present and future surface infrastructures and activities.

The Préfet initiates a PPRM procedure by specifying in particular the investigation perimeter as well as the nature of risks taken in account. In addition to the involved administrative services, local councils are also consulted and the PPRM project is subjected to a "public investigation" of the concerned population. At the end of the various consultations, the PPRM, possibly modified, is approved by a Préfet decree. The defined regulations become applicable and have authority on the Local Urbanism Documents established in each French city, by the municipal council.

A PPRM elaboration may be divided in 4 major stages:

- The informative stage aims to collect available information (or in case of absolute necessity to undertake complementary investigations). It requires very careful data collection both on site and from archives. It leads to the elaboration of an informative map, which constitutes an essential communication support because it contributes to justify the prevention step undertaken by analysing the disorders and harmful effects in the past.
- The hazard evaluation stage aims to locate and to hierarchise the exposed zones, according to the intensity of the foreseeable phenomena and their pre-disposal to occur in each zone. This evaluation stage does not integrate the nature of surface occupation. It leads to the establishment of hazard maps, which locate the hazardous zones (figure 3).

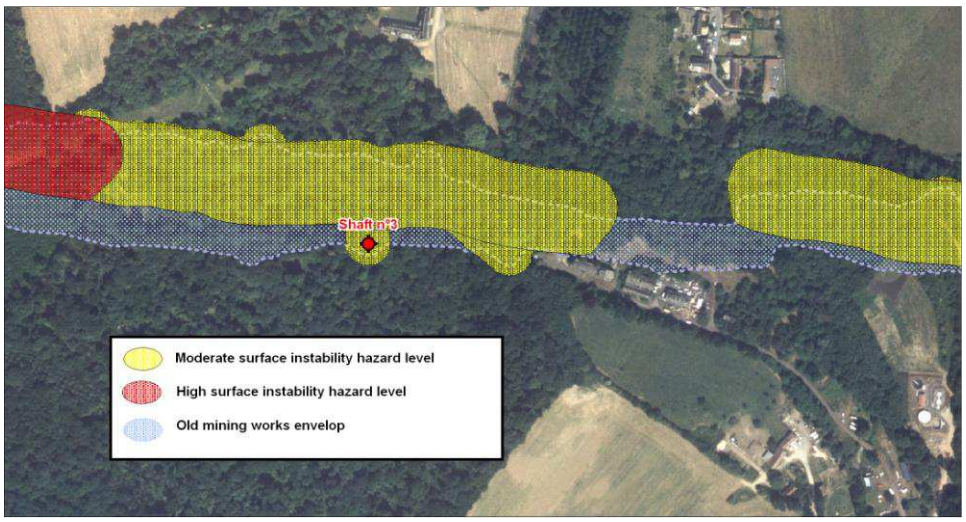

Figure 3. Example of a hazard map above abandoned iron mines (NW of France)

- The vulnerability appreciation stage aims to characterise the existing vulnerability in the areas subjected to one or various phenomena and to identify the potential future projects which could develop within these areas. It enables to recognise the population subjected to different

risk levels. In particular, the most sensitive equipment or buildings (hospitals, schools, etc.) are considered. This stage leads to the setting up of a vulnerability map.

- The regulation stage aims to define homogeneous zones in term of land use management (prohibitions, regulations or recommendations) concerning existing equipment as well as new projects. The principle of this zoning is based on a "crossing" of hazard levels with nature of surface occupation (vulnerability levels). Directly connected to this zoning, some regulatory rules are established in order to manage, in a clear and operational way, the land use occupation for any zone subject to hazards.

The French Ministry in charge of Industry and Mines asked INERIS to develop a methodological guideline describing the recommended procedure for the elaboration of a PPRM whatever the nature of foreseeable phenomena (surface instabilities, floods, gas emission). This document, published in 2004, is now available for organisations and services involved in PPRM procedure (INERIS, 2004).

Since MRPP initiation, more than forty abandoned mine sites located throughout France have been studied considering the informative and hazard steps of MRPP procedure (figure 4). To these sites, one has to add the whole Lorraine iron ore field whose analysis has been initiated prior to MRPP framework. For this basin, about a hundred under-mined cities have been analysed producing hazard and risk maps.

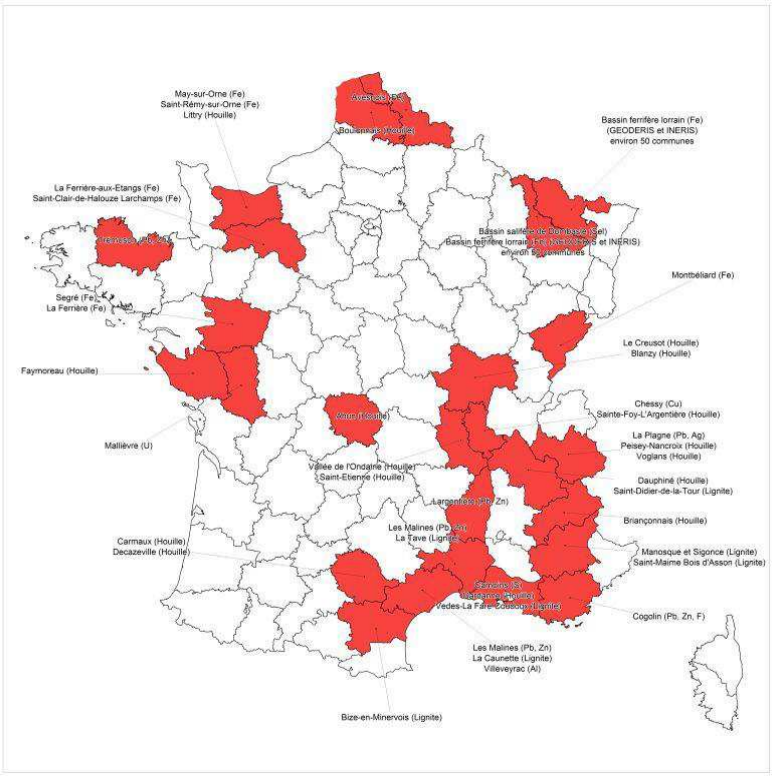

Figure 4. Location of the abandoned mining sites, where MRPP have been implemented.

The initiated MRPP have concerned the main mining ore basins exploited in France. One may quote metal mines (lead-zinc of Centre and Brittany, copper in the Alps, uranium in Centre-West, etc.), major iron ore fields (Lorraine, Normandy) and many coal basins (Provence, Centre-South, etc.). The next important step of MRPP implementation will be the elaboration of informative and hazard studies over the major salt basins (Lorraine, Jura, South-West). The beginning of these studies is planned for 2008.

Until now, the great majority of the studied sites has concerned the "surface instability" hazard. Among those instabilities, the sinkhole phenomenon is of the first importance. It deals with shallow abandoned mining works (few tens metres deep) as well as the sectors with many mine openings (shafts, adits, etc.). Although generally less sensitive, hazards related to mine gas emission have also been highlighted in many abandoned mining sites. Much more locally, "environmental hazards" have been identified in some unfavourable contexts mainly resulting from the exploited ore (lead, zinc, silver, etc.).

4.5. The "Mining Sites Screening Process"

About 4000 mining titles (concessions, exploration agreements) have been granted throughout the whole metropolitan French territory. Taking into account the current rate of MRPP implementation (about fifteen per year), one can easily estimate that the period needed to perform all the requested analysis might last several decades. It was thus essential to establish priorities so that the most sensitive sites could be treated prior to the others.

This is the main objective of the "Mining Sites Screening Process" that is to say:

- to hierarchise the order of the future MRPP implementation,
- to identify quickly the critical contexts requiring urgent safety measures.

This ambitious program, carried out under the responsibility of GEODERIS with the collaboration of INERIS and BRGM, has required about 3 years. This innovating process consisted in reviewing all French mining sites in order to classify them according to their risk level (considering surface instabilities). It also contributed to perform a simple and quick risk qualification for 200 most sensitive mining sites (figure 5).

The site selection methodology has consisted in hierarchising progressively, through various stages, the sites according to the available data. The first stage uses the information available in GEODERIS mining site GIS-assisted database. This information makes it possible to localise roughly mining works and to provide useful technical data for a simple risk evaluation. For the identification of equipment and infrastructures on surface, one has to work with recent topographic maps (scale 1/25000). The crossing of the mining information with the nature of surface occupation enables to put in the lowest rank a first group of sites being either far away from any surface structure or without any risk of surface instability.

The sites that have not been "eliminated" at first step require complementary information on mining data and surface occupation (this step requires archive research and site visit). Thanks to the further collected data, the remaining sites are then classified according to their more or less "risky" character using decision-aid software based on multi-criteria analysis. The criteria list, as well as the respective weights, has been established by an expert college functioning as a steering committee. This hierarchisation process made it possible to recognise the 200 most critical sites. For these specific sites, simplified risk evaluation and cartography are undertaken systematically. To optimise the results reliability and the work effectiveness, the screening process has been performed region by region, the task being delivered by GEODERIS to INERIS and BRGM regarding their complementary areas of activities.

By the end of 2007, the operation, initiated in January 2005, has been completed for the Southern and Western regions. It will be totally finished for the Northern and Eastern regions by beginning of 2008. The first results indicate that approximately 60% of the reviewed mining titles do not generate any risk of ground movement, either because of the absence of stakes or of mining works able to generate significant hazards. Approximately 30 % of the titles may generate potential future risks, but with a limited extent of mining works and/or the

limited occupation of the surface in the surroundings. Finally about 10 % of the titles required further risk assessment studies. Except few large coal and iron basins, the existing French mining sites are, for a very large majority, of rather restricted extension. Nevertheless, they have often developed very close and even right under inhabited areas. The very old brown-coal and hard-coal mines, generally quite shallow, constitute the main part of this category.

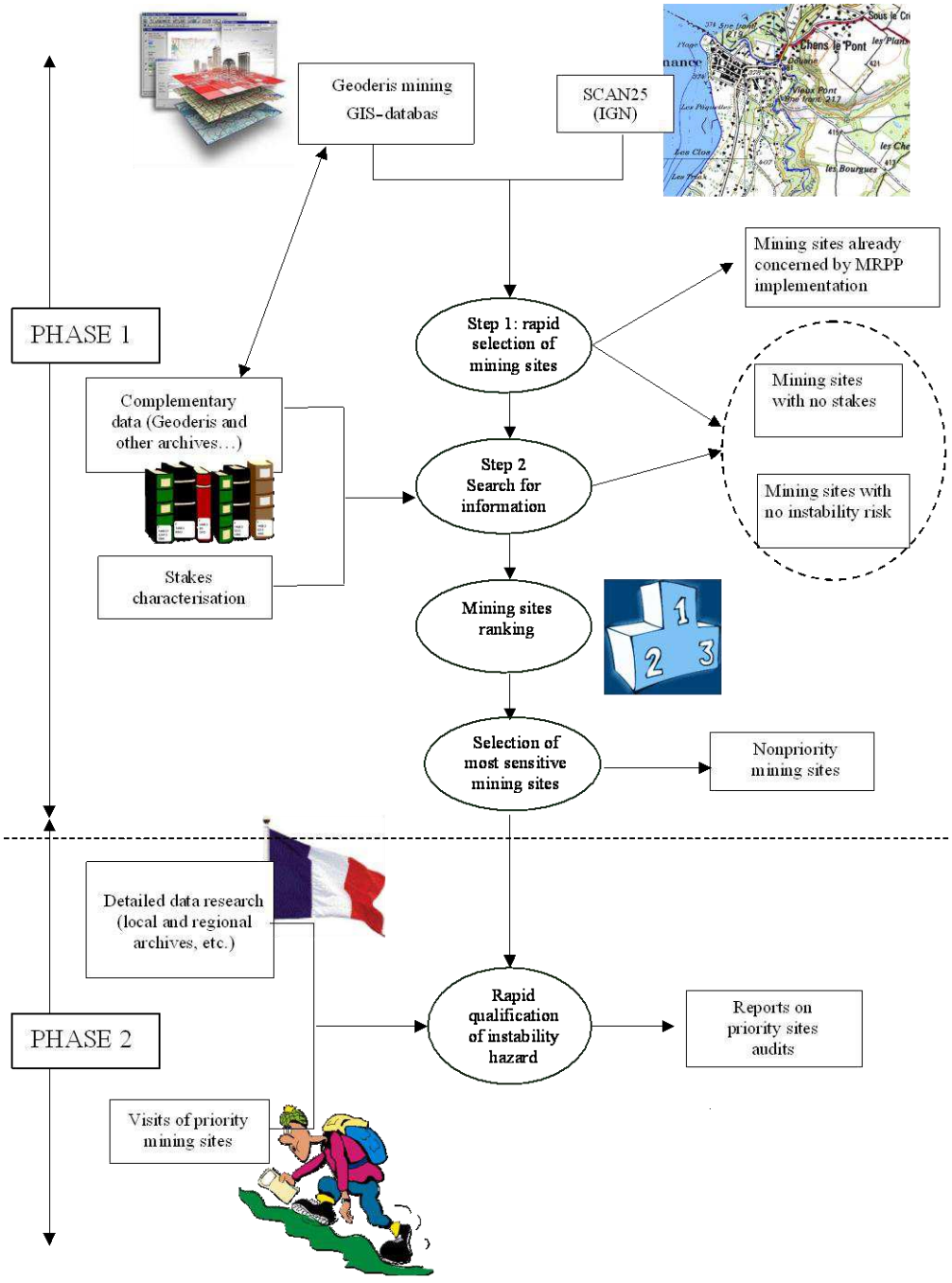

Figure 5. Mining sites screening process principles.

Taking into account the recommendations given during the simplified risk assessment step performed over the 200 most sensitive sites, it appears that almost ¾ of them require further risk evaluation. Different levels of priority have been established, depending mainly on the existing occupation and the potential land use development in the coming years.

The remaining ¼ relates to areas located far from inhabited areas for which the state of knowledge in relation with mining works appears there to be enough. Finally, for almost 60 %

of the 200 studied sites, local risky situations (untreated shafts, possible sinkholes development in inhabited area…) have been recognised. Complementary specific investigations have thus been suggested.

4.6. Management and Use of GEODERIS Mining Database

Acquisition, management and use of existing data are of major importance for a risk prevention policy. For this reason, GEODERIS develops, informs and uses, since 2001, a database for the French mining sites and titles (figure 6). This tool, addressed to the various actors involved in post-mining management (Administration, communities, experts…), aims to register, schedule and ease use of available data related to disused French mines. The database and its structure are in permanent evolution in order to answer to the users needs. The database covers the whole national territory.

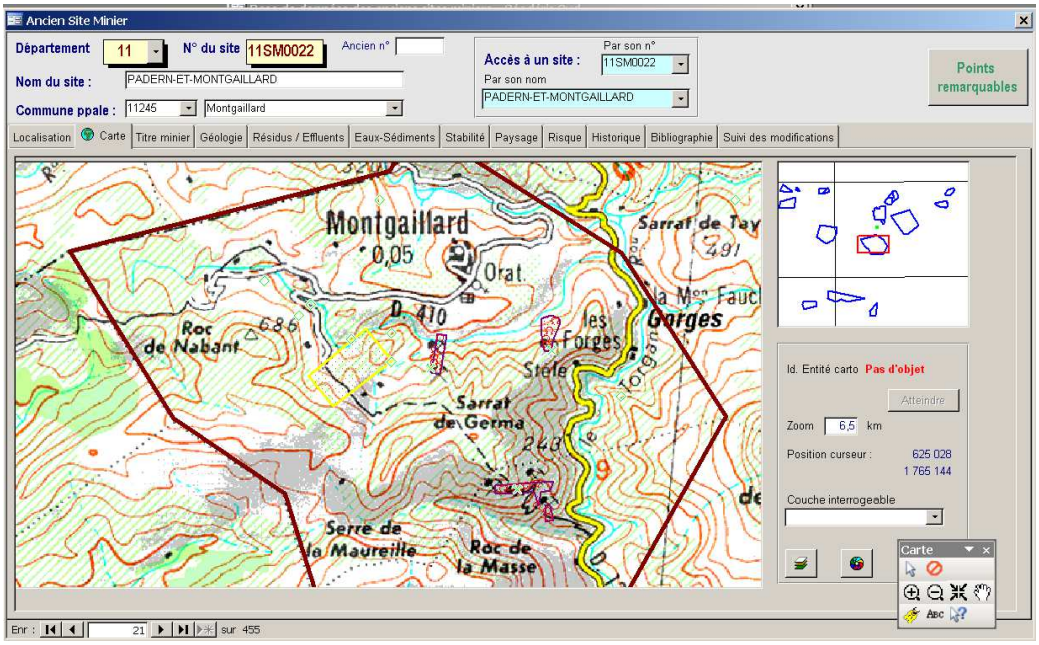

Figure 6. A screen hard copy of GEODERIS Mining GIS-database.

The database includes mining titles (administrative concession perimeters, exploration authorisation) as well as mining sites (exploitation sectors known more or less precisely). Thus a title can contain zero, one or more exploitation sites. On the contrary, a mining site may have developed within a title or across several titles or even being located away from any official concession.

It is possible to bind a site or a title to various types of documents (photographs, maps, scanned documents, etc.) like the results of the studies undertaken on this site (expert report, risk zoning, etc.). The database, developed under ACCESS®, is linked with the software of Geographical Information System (GIS) MAPINFO® so as to allow visualisation on adapted cartography (Scan 25 of IGN for example) of the various elements (titles, sites, works, zones of risks, etc.). The database is of a very simple and intuitive use, not requiring any particular knowledge of specialised software (Dommanget, 2006).

The database gathers administrative information (beginning and of end of the mining titles, information on owner…), technical data relating to underground or open pit work (mining methods, depth, etc.), mine openings (shaft, adit, gallery) as well as deposits (tailings, spoil heaps). It also makes it possible to gather important information on geology of the ore

(cluster, layer, vein, etc.) and related to the existence of old mining disorders having affected the site previously (number, nature, date of occurrence, etc.).

A very detailed attention will have to be paid in the coming years to come to the census and then to the risk analysis of the former mining deposits on surface. As a matter of fact, the European directive on the analysis and the risk management related is to be taken into account in French regulation.

4.7. The Monitoring of Post Mining Risks

The law of March 30 1999 also called "post mining law" stipulated a very important issue: the monitoring of post-mining risks. Prior to this date, mining operator was supposed to treat, by any adapted method, in every context and situation, the foreseeable risks in order to prevent or cancel them. This was not always possible at long term and some important problems could occur after the Concession-Holder withdrawal.

The 1999 "post-mining law" stipulates explicitly that in case geological and mining contexts do not allow, for some technical or financial reasons, identification of reasonable measures making possible definite treatment of the risk, it is the Concession-Holder's responsibility to monitor the risk in order to assure public safety in preventing foreseeable accidents. Monitoring may also be undertaken during a transient period, when risk management measures are performed (backfilling, moving of people). To transfer the monitoring management to the State before mine closure, the mining companies must deposit funds allowing monitoring of the hazardous areas during a period of ten years. In case of abandoned mines, the authorities take over the permanent monitoring.

INERIS is fully involved in this operational monitoring management as well as in the technological development of innovating equipment. Microseimicity is widely used to monitor hazardous areas using concepts similar to earthquake monitoring (figure 7). Rock mass fracturing produces acoustic emissions that induce small ground tremors recorded by sensors (geophones and accelerometers). Data processing of microseismic events is based on waveform and frequency analysis, seismic energy and magnitude calculations, location of the seismic source and determination of focal mechanism that finally give information on the source process.

Up to now, in Lorraine iron mining field (NE of France), about 15 towns are being monitored by microseismic networks constituted by several sensors. The seismic data are recorded and treated thanks to SYTMIS software, developed by INERIS. Seismic events are immediately and automatically transferred to INERIS monitoring centre in Nancy via phone transmission.

Among other parameters, two general and basic data are instantaneously processed: the number of events per hour and the cumulative seismic energy. If one of these parameters is beyond the pre-defined thresholds, an alarm is triggered. Several monitoring teams have been formed respectively for night and day duty and technical maintenance. They have in charge the permanent, 24 hours/day system supervision. The expert on duty receives an automatic phone call on the dedicated mobile phone and is responsible for the analysis of microseismic data and the follow up of the alarm up to its end. Specific internal procedures are followed, which ensures the best quality of the alarm management. This monitoring is one of the key points of the overall risk management process supervised by the civil protection administration and local authorities, responsible for taking appropriate decisions and related operations.

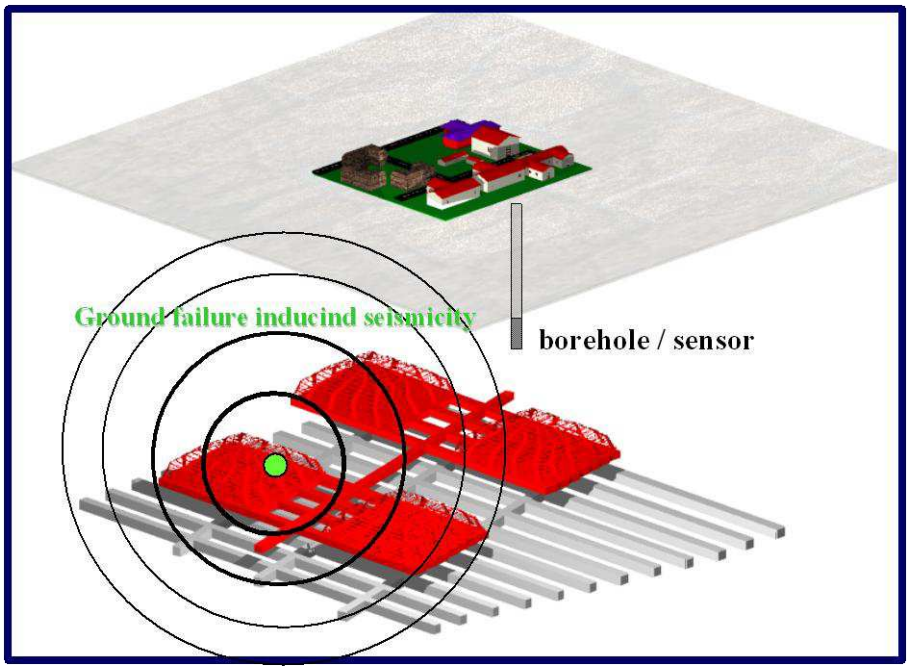

Figure 7. Example of a micro seismic monitoring station installed in the Lorraine iron ore basin

In terms of technological improvement, the major development axis is the implementation of a Global Geotechnical Monitoring System dealing with different coupled and complementary monitoring techniques from a unique centralised operational monitoring system. This system will integrate real-time seismic technology, automatic classical geotechnical monitoring as well as "real time GPS" surveying technology.

The objective is to develop, in the following years, an operational, cost effective monitoring GPS micro network technology able to give fundamental information on quasi static ground surface movement at a rather large scale. Such features will highly optimise quality and amount of data to be analysed, costs related to data transfer, archiving, etc. while increasing significantly lifetime of some parts of equipment set up on site. In order to enhance its capacities in operational monitoring as well as technological development, INERIS founded in 2003 a National Centre of Monitoring of Ground and Underground Risks Monitoring. The task of this expertise body, taking benefit of several scientific partnerships, will be to answer to the practical needs of the authorities and of the mining operators concerning monitoring of post mining risks.

4.8. Damage Compensation and Preventive Evacuation

The mining operator is responsible for the damages that can result from his activity, without any time restriction (even long time after mine closure). So it is his responsibility to compensate victims of mining damages. Nevertheless, it has to be proven that the damages resulting from any another origin can not be attributed to another origin.

One of the major innovations of the "post mining law" results in the guarantee of the State. In order to assure that victims are compensated in case of Concession-Holder disappearance or insolvency, the legislator expected the State to deal, in this specific context, with the victims' compensation. The post mining law also stipulated that, in case of a major mining hazard threatening seriously public safety, the goods exposed to this risk may be expropriated in case the protection and/or prevention measures are more expensive than the expropriation cost.

This statutory process is restricted to the cases of major risks and extreme urgency. Due to the strong socio-political constraints, this step is the ultimate risk management solution, when any other possibility appears to be inadequate (for technical and economical reasons). During last years, about hundred houses have thus been expropriated throughout France. People have then be relocated in other residences.

5. National Post-Mining Risk Management Organisation

The role of the French State concerning post-mining consists in identifying the risky abandoned mining sites and evaluating the corresponding risks in order to determine the suitable preventive measures able to secure, when necessary, population and activities.

As described before, these measures can take the form of reinforcement works or constraints applied to town planning (MRPP). Moreover the French State has sometimes to assume exploitation and maintenance of water stations (pumping or physicochemical treatment), installations of firedamp management or devices of monitoring when concession holders no longer exist and public safety is threatened.

To assume these missions, the State is based, at the national level, on some Services of the Ministry in charge of Industry (Department of the Regional Action, Quality and Industrial Safety and General Department of Energy and Raw Materials). At the regional level, 24 "Underground Divisions" of the Regional Departments of Industry, Research and Environment (DRIRE) manage technical and administrative supervision of mining and post-mining activities. Beyond the regional level of DRIRE, three interregional "post-mining poles of competencies" were set up in Metz (NE of France), Alès (SE) and Caen (NW).

Moreover, the State initiated the creation of a public organisation GEODERIS for the technical support to the administration for the study of the behaviour of the mining works, the characterisations of the possible risks and the determination of the measures to be taken to prevent or manage the risks. This Public structure clusterizes skills of the National Institute of Industrial Environment and Risks (INERIS) and French Geological Survey (BRGM).

For the operational post-mining management, the State entrusted to BRGM missions of prevention, monitoring and safety concerning the disused mining concessions. This organisation assures, on behalf of the State, a control of the securing works when necessary. It also manages the hydraulic installations (pumping and treatment) transferred by the mining operators to the State.

Finally, in order to provide a scientific support needed for expertise and risk management, a Scientific structure, GISOS, has been created. Four public organisations (INERIS, BRGM, Polytechnical Institute of Lorraine, School of Mines of Paris, etc.) belong to this structure. GISOS has three major axis of research: comprehension, characterisation and modelling of mechanisms and structures, role of fluids (water and gas), risk analysis principles and development. Every 2 to 3 years, GISOS organizes an international post-mining symposium, to share with foreign experts the knowledge and expertise improvements in the area of post-mining.

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